EXPLOSIVE DESTRUCTION SYSTEM FOR DISPOSAL OF CHEMICAL MUNITIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a nonprovisional continuation of provisional application Ser. No. 60/192,967, filed on March 29, 2000, and claims the benefits thereto.

GOVERNMENT INTEREST

The invention described herein may be manufactured, used and/or licensed by or for the United States Government.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to mobile devices capable of destroying, treating, and/or disposing of munitions. More particularly, the present invention relates to transportable devices capable of treating explosively configured chemical munitions providing the capability of a contained destruction of said munitions. Most particularly, the present invention relates to devices capable of explosively destroying and detoxifying chemical munitions within a gas-tight enclosure, i.e., without venting of any explosion combustion products or toxic chemicals during detonation, and providing for the subsequent neutralization or detoxification of any toxic chemicals present such as industrial chemicals and chemical warfare agents.

2. Description of the Related Art

The United States Department of Defense is required under Public Law 102-484, Section 176, to safely destroy all U.S. non-stockpile chemical warfare materiel (NSCM).

The priority for destroying NSCM has increased because of the Chemical Weapons Convention (CWC) negotiations and the realization that some Chemical Warfare Materiel (CWM) are in the public domain and others are located close to public areas.

The U.S. Army Program Manager for Non-Stockpile Chemical Materiel (PMNSCM) has developed a transportable Explosive Destruction System (EDS) to provide the capability of destroying explosively configured munitions unsafe for transport or storage. The mission of the EDS is to destroy explosively configured chemical warfare munitions, contain the blast and fragments created when opening the munition, and treat the chemical fill of the munition, without release to the environment.

Devices for safely handling explosives are well known in the art. For example, Fylling, U.S. Pat. No. 3,820,479, describes a mobile container in which an explosive, such as a time bomb, can be placed after discovery for transport to a suitable location for disarming. It includes a ballistic grille to vent explosion gases in an upwardly direction. Hickerson, U.S. Pat. No. 4,027,601, describes a container for explosive devices that includes inner and outer cylinders to substantially contain detonation fragments and the blast. This device is intended to transport improvised explosive devices (IEDs) or homemade bombs to a safe disposal area. Benedick et al., U.S. Pat. No. 4,055,247, describes an explosives storage container designed to absorb and contain the blast, fragments, and detonation products from an unintentional detonation of the contained explosive or munition. Here again, the device is designed to safely transport and store a munition and includes distinct layers to absorb the explosive energy. All of these devices are intended to provide a safe means for transport and/or storage of an explosive, but

none are designed for purposeful detonation in order to destroy the explosive, and none are gas-tight or otherwise designed to treat toxic or hazardous chemical payloads.

Holmlund et al., U.S. Pat. No. 4,478,126 describes a chamber for containing the effects arising from explosions or detonations whether initiated intentionally or unintentionally inside the chamber. The chamber comprises a cylindrically formed mantle with associated sealed ends. Ohlsson, U.S. Pat. No. 4,478,350, describes a spherical container or chamber to protect the surroundings by containing critical stages in the manufacture of explosives, or to store or serve as a bunker for explosives. Ohlson, U.S. Pat. No. 4,621,559, describes a readily replaceable liner to be used in detonation chambers and capable of receiving fragments to mitigate the effects of splinters produced by explosions, and in which only damaged parts of the liner need to be replaced; and Ohlson, U.S. Pat. No. 4,632,041, describes a cylindrical blasting chamber which can contain high pressure and splinters produced by an explosion. The blasting chamber includes a double-wall design such that explosive pressure is distributed fairly evenly between the inner and outer walls. However, these devices are not intended to be used for the safe detonation and chemical treatment of explosively configured chemical warfare munitions.

Donovan, in U.S. Pat. Nos. 5,613,453 and 5,884,569, describes methods and an apparatus for containing and suppressing explosive detonations, whether for the explosive working of metals or for the disposal of unwanted explosive munitions. Said apparatus includes a linear array of vent pipes to vent the explosion's gaseous combustion products for subsequent treatment in a scrubber. This apparatus includes a double-walled steel explosion chamber anchored to a concrete foundation, and double-walled access and vent

doors. Energy absorbing means such as water-filled bags and conventional chain blast mats are also employed. This device is not intended to be readily mobile, is not equipped for chemical neutralization, nor is it gas-tight so that it can safely contain toxic chemical warfare agents and byproducts.

Explosive chambers have also been developed for controlling and suppressing the detonation of explosives used for industrial applications such as surface hardening of manganese steel rail, welding of metallic components, and compression molding of components from powders. Most of these applications permit the release of the explosion combustion products into the atmosphere. See, for example, U.S. Pat. Nos. 5,419,862 and 4,100,783 issued to Hampel and Gambarov, respectively. Deribas U.S. Pat. No. 4,085,883 and Minin U.S. Pat. No. 4,081,982 disclose spherical containment vessels for explosive working of metals, the latter also including an internal liquid spray for neutralizing toxic byproducts of the explosion. Here again, these devices are intended to explosively work or harden a workpiece, are not intended to access the interior of the workpiece or otherwise destroy it, and are not gas-tight or otherwise suitable for disposal of chemical warfare munitions.

In view of the foregoing, it is therefore highly desirable to provide an apparatus which can be used to dispose of chemical warfare munitions by explosively accessing the interior of said munition within a gas-tight vessel so that all detonation products including any highly toxic chemical warfare agents are contained in a gas-tight manner, and subsequently treating the remains of the munition and the contained detonation products with means to neutralize and detoxify any remaining chemical warfare agent within the gas-tight vessel.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an apparatus for safely destroying explosively configured chemical munitions, said apparatus comprising a sealable gas-tight explosive containment vessel, a fragment suppression system contained within said vessel, and means for explosively accessing the interior of said munition when it is placed within the fragment suppression system.

It is another object of the present invention to provide an explosive containment vessel that is mobile and can be sized in various embodiments capable of containing at least 500 individual detonations of about 1.0 pound of TNT, or up to 500 individual detonations of about 3.5 pounds of TNT.

It is still another object of the present invention to provide a means for neutralizing or detoxifying any toxic chemicals contained within said vessel.

It is yet another object of the present invention to provide a means for heating said containment vessel to facilitate the neutralization of toxic chemicals therein.

Still another object of the present invention is to provide a means for agitating the contents of said containment vessel in order to facilitate the toxic chemical neutralization process.

It is still a further object of the present invention to provide means for sampling both liquid and gas from the interior of said containment vessel in order to verify the neutralization of any toxic chemicals that were contained therein.

Finally, it is another object of the present invention to ensure the apparatus is easily portable so that explosively configured munitions can be treated and disposed of where they are found without having to transport the munition.

The foregoing and other objects and advantages of the present invention will appear from the following detailed description. In the description, reference is made to the accompanying drawings which form a part hereof, and in which there is shown by way of illustration and not limitation, preferred embodiments. Such description does not represent the full extent of the invention, but rather the invention may be employed in different arrangements or configurations according to the breadth of the invention as defined in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 provides a longitudinal cross-sectional view of the explosive destruction system of the present invention.

FIG. 2 shows a detailed cross-sectional view of the all-metal seal of the present invention as identified on FIG. 1.

FIG. 3 shows an end view of the system with an open vessel door.

FIG. 4 is a side view of the explosive destruction system of the present invention.

FIG. 5 shows a view of the inside of the system's door including spray nozzles and drains taken along line 5-5 of FIG. 4.

FIG. 6 provides a top view of the fragment suppression system of the present invention.

FIG. 7 shows a cross-sectional side view of the fragment suppression system of the present invention taken along line 7-7 of FIG. 6.

FIG. 8 is a side view of the fragment suppression system of the present invention.

FIG. 9 is a perspective view of the trailer-mounted explosive destruction system of the present invention showing the embodiment having a hydraulically operated vessel agitation mechanism.

FIG. 10 is an end view of the explosive destruction system showing the closed door and valve manifold.

FIG. 11 is a side view of the explosive destruction system showing the embodiment having a motor-driven vessel agitation mechanism.

FIG. 12 is a perspective view of the trailer-mounted explosive destruction system of the present invention showing the embodiment having a motor-driven vessel agitation mechanism.

FIG. 13 shows two of the liquid and gas sample collection systems for the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, like reference numerals represent identical or corresponding parts throughout the several views.

Turning now to FIG. 1, a longitudinal sectional view of the explosive destructive system **10** is shown. The system comprises a cylindrical containment vessel **12** having a hinged

sealable door **14**. In a preferred embodiment of the invention, both vessel **12** and door **14** are fabricated from 316 stainless steel forgings. Of course, the size of the vessel **12** will vary according the amount of explosive material the user is required to contain. For example, a vessel **12** designed to contain at least 500 detonations of about 1.0 pound of explosive (TNT equivalent) comprises about a 6.5 cubic foot cylindrical vessel having an inside diameter of 20 inches with 2-inch thick walls. The hinged door **14** is the same diameter as the vessel **12**, allowing easy access for inserting munitions and removing debris. In this embodiment, the door **14** is secured with a large, two-piece clamp **16** that is fastened with four threaded rods **18**. FIG. 3 shows an end-view of the system **10** with an open vessel door **14**, vessel **12**, clamp **16** and rods **18**. In a preferred embodiment, the vessel door **14** is sealed to the vessel **12** using a Grayloc® all-metal seal **20**, shown in detail in FIG. 2, to contain the detonation products and chemical fill. A rubber O-ring **22** provides a mechanism for leak testing of the sealed vessel **12**. When properly installed and sealed, the helium leak rate through the metal seal at 50-psi differential pressure is less than $1x10^{-3}$ mbar-l/sec. Also shown is the door protector plate **39,** which shields the interior surface of the vessel door **14** from blast fragments created during detonation.

As shown in FIG. 3, once a munition has been recovered it is placed in the vessel **12** by positioning the munition within a fragment suppression system **11**. A top view of the fragment suppression system **11** is provided in FIG. 6 and a cross-sectional side view is provided in FIG. 7. The fragment suppression system **11** comprises a steel cylinder **13** separated longitudinally into two sections, the lower half including a cradle **15** which supports the suppression system **11** inside the vessel **12**. End plates **17** are attached to the

cylinder ends to enclose the munition once it is placed in position. Stopper block **41** is positioned below cylinder **13** and is used to stop any penetrating shaped charge jet before reaching the interior wall of vessel **12**. The fragment suppression system **11** is necessary to mitigate the effects of high-velocity fragments that could damage the interior of the vessel **12** during operations. In addition, door protector plate **39** provides additional protection to the electrical feed-throughs **24** and the spray nozzles **26** and drains **28** located on the interior surface of the door **14**.

Once the munition is positioned within the fragment suppression system **11**, as shown in FIGs. 7 and 3, it is placed inside the vessel **12,** which is then sealed by closing door **14**. In a preferred embodiment, the inside of vessel door **14,** as shown in FIG. 5 (with protector plate **39** not shown), includes electrical feed-throughs **24,** for connecting to high-voltage exploding bridge wire detonators **25** (shown in FIG. 7), and spray nozzles **26** and drains **28**. Near the center of the door **14** are the spray nozzles **26** for injecting the treatment chemicals into the vessel **12**, and at the bottom are drains **28**, preferably having sieves to prevent clogs while removing liquid effluent. In a preferred embodiment, there a four electrical feed-throughs **24** with terminal connectors providing a means for wiring detonators **25** within the vessel **12**.

Once the munition is positioned in the fragment suppression system **11**, within the vessel **12**, the door **14** is sealed. At that time, the contents of the munition must be exposed and the burster destroyed before the chemical fill can be treated. In a preferred embodiment, this is accomplished through use of a linear shaped charge **19** and conical shaped charges

21 as shown in FIG 7. In practice, the linear shaped charge **19** and the conical shaped charges **21** are attached to the upper and lower sections of the fragment suppression system **11** before the munition is placed in the vessel **12**. The detonators **25** are attached to the charges **19** and **21** and cables are connected to the detonators **25**, strain relieved and electrically shorted for safety. The munition is positioned in the pre-assembled bottom section of the fragment suppression system **11**. The pre-assembled top section of the fragment suppression system **11** is placed on top to complete the system, and the entire unit is positioned inside the vessel **12**. The final fire system connections are made, the vessel door **14** is closed, strain relieved and then electrically shorted until the system is fired.

The use of shaped charges **19** and **21** to access the interior of the munitions is simple, safe, and repeatable. In a preferred embodiment, a single preformed length of copper linear shaped charge **19** is used to open the main body of the munition. Of course, the shaped charges **19** and **21** may comprise copper, lead or any other suitable material well known to those of skill in the art. The linear shaped charge **19** is attached to the lower half of the fragment suppression system **11** for ease of assembly and to maintain the proper standoff distance for an optimum cut. Experiments with three different munitions of interest have demonstrated that the linear charge **19** makes a complete cut in the munition, separating it into two pieces and exposing the chemicals contained therein. Detonators **25** are connected to the linear shaped charge **19** at each end for increased reliability.

In a preferred embodiment, two copper conical shaped charges **21** are used to break open the burster charge canister in the munition and detonate the burster explosives. The conical shaped charges **21** are positioned on the upper half of the fragment suppression system **11** above the case of the target munition providing a predetermined standoff distance. The conical shaped charges **21** are fired in the direction of the burster at approximately the same time as the linear shaped charge **19** is fired.

The conical shaped charge **21** is designed to impact the munition's burster with sufficient energy to detonate the burster. The burster explosives can be any composition used by a variety of nations that have been involved in the manufacture of chemical weapons; however, they will likely be Tetryl, TNT or a combination of both. Of course, with recovered munitions the condition of the burster explosives is uncertain. It is not known whether the explosives were cast or pressed, at what density the material was manufactured, or what the effects of aging or contamination by the chemical fill may have on the detonation properties. All of these issues lead to uncertainty as to the detonation sensitivity of the burster explosives. However, the burster explosives do not need to be completely destroyed by the shaped charge **21** attack, as subsequent chemical treatment processes carried out in the vessel **12** will destroy residual explosives along with the chemical fill as long as the burster well is penetrated by the shaped charges **21**. In any event, any remaining burster explosives will not be sensitized to shock or otherwise an explosive hazard.

In a preferred embodiment, the conical shaped charges **21** comprise a 32.2-gram, Composition A-3, multi-tapered copper conical shaped charge available, for example, from BAE Systems. For safety, exploding bridge-wire detonators **25** are used to initiate the shaped charges. These detonators are very insensitive to unexpected or undesirable energy inputs (static, impact, etc.). A high-energy firing system is required to initiate these detonators. Although this detonation system is preferred for safety reasons, the system could also be adapted to operate using standard blasting caps and a low voltage firing system which are well know to those of skill in the art.

A firing system initiates the linear shaped charge **19** to open the munition and the conical shaped charges **21** to penetrate the burster well. In a preferred embodiment, the firing system comprises a high-voltage capacitor discharge unit (CDU) capable of reliably firing four detonators **25** (1.5 x 40 mil exploding bridge wire) over cable lengths of up to 50 feet. The firing system consists of the CDU, a high voltage power supply, a control module, monitoring and diagnostic equipment, and safety controls. The CDU comprises a 1 micro-Farad (μF), 3kV capacitor triggered from a 150-volt trigger module. A high-voltage power supply transforms 24 V DC to 3000 V and 150 V to power the CDU and trigger module, respectively. A control module makes the connection from the power, arm, and trigger signals to the appropriate modules. An operator can remove the entire firing system from the containment vessel **12** by using 50 foot detonator cables, and if desired, the operator can remove the control module an additional 200 feet from the firing system panel during operation.

The destruction of chemical-agent containing ordnance or munitions requires that the chemical-agent fills and energetics be converted to waste that can be safely handled and disposed of at commercial treatment and disposal facilities. In a preferred embodiment, the explosive destruction system **10** uses a low-pressure (< 300 psi), low-temperature treatment method to transform chemical warfare fills to safe, less toxic species. This neutralization process relies on specific treatment chemicals which have been proven to be effective at detoxifying or neutralizing chemical warfare agents. The end products of the treatment reactions are mixtures of aqueous and/or combustible organic species that can safely be handled as commercial hazardous waste. In some cases, the chemical fills may require no treatment once the explosive hazard has been eliminated using the linear and conical shape charges.

The treatment is carried out inside the containment vessel **12** after the munition has been opened by the linear shaped charge **19** and the conical shaped charges **21** so that there is no transfer of untreated chemical warfare fill. As shown in FIG. 9, treatment chemicals and water are stored in tanks **27** positioned on a trailer **29** on which the explosive destruction system **10** is mounted making the system easily transportable for rapid deployment in emergency situations. In one embodiment the treatment system comprises three 25-gallon, stainless steel tanks **27**. The treatment chemicals contained in tanks **27** are pumped through piping into the containment vessel **12** through spray nozzles **26** located in the vessel door **14**. In a preferred embodiment, the tanks **27** are heated to make viscous liquids easier to pump and to speed up the treatment process. As shown in FIG. 10, a valve manifold **37** on the vessel door **14** allows the operator to control the flow of

chemicals, collect samples to confirm the treatment is complete, and drain the liquid effluent. Gaseous effluent resulting from the treatment process is vented through any appropriate air pollution control technology, such as, silica gel/ASZM-TEDA carbon filter.

The sample collection system comprises a system of tubing, valves, vacuum storage reservoir, and sample bottle or gasbag. As shown in FIG. 13, a plurality of sampling systems can be mounted on door **14**. These systems comprise a first valve **49** positioned in-line between the tubing end inside the door **14** and a sample bottle **59** having its own valve **53**. Couplers **51** are located on either side of valve **53**. Following the bottle **59** and valve **53** is a vacuum reservoir **57**, an additional valve **55** interposed between the vacuum reservoir **57** and a vacuum source or reagent or inert gas source. In order to sample liquid from inside the vessel door **14**, valve **49** is closed to seal the contents of vessel **12**, and valves **55** and **53** are opened to a vacuum source to evacuate the sample bottle **59** and vacuum storage reservoir **57**. Valve **55** is then closed, and with sample bottle valve **53** open, valve **49** is opened allowing liquid contained inside vessel **12** to flow into the sample bottle **59**. Sample bottle valve **53** is then closed to preserve the liquid sample in bottle **59**, and reagents and inert gas are pumped through the tubing and vacuum storage reservoir **57** for decontamination purposes. Finally, with valve **49** closed, the couplings **51** are opened and the sample bottle **59** with valve **53** are removed for analysis and a clean bottle reinserted in-line. Collecting a gas sample is similar except that valves **55** and **53** are closed, a gasbag is installed in lieu of the bottle **59**, and valve **49** is opened. Valve **53** is then slowly opened to inflate the gasbag with gas sample.

Table 1 provides a list of the chemical agents that can be treated by the explosive

Symbol	Common Name	Chemical Name	Chemical Structure
BA	Bromacetone	Bromo-2-Propanone	$BrCH_2$-CO-CH_3
CA	Bromobenzylcyanide		Br-C_6H_4-CH_2-CN
CG	Phosgene	Carbonyl dichloride	Cl-CO-Cl
CK	Cyanogen Chloride	Chlorine Cyanide	ClCN
CL	Chlorine	Chlorine	Cl_2
CN	Chloroacetophenone	Chloromethylphenylketone	Cl-CH_2-CO-C_6H_5
CNS	Mixture of CN, PS, and chloroform		
CNB	Mixture of CN, benzene, and carbon tetrachloride		
DA	Diphenylchlorarsine	Diphenylchlorarsine	$(C_6H_5)_2AsCl$
H HS HD; HT	- Mustard - Sulfur mustard - Distilled mustard; 60% mustard, 40% vesicant T	2, 2'-Dichloro-diethyl sulfide	$(Cl\text{-}CH_2\text{-}CH_2)_2$-S
L	Lewisite	1-Chloro-2-dichloroarsinoethylene	Cl-CH=CH-$AsCl_2$
NC	80% PS, 20% $SnCl_4$		
PD	50% CG, 50% DA		
PG	50% PS, 50% CG		
PS	Chloropicrin	Nitrotrichloromethane	NO_2-CCl_3
GB	Sarin	Isopropyl methylphosphonofluoridate	
VX	Nerve Agent	O-ethyl-S-(2-isopropylaminoethyl) methyl phosphonothiolate	

Table 1: Chemical Fills That Can Be Treated In The EDS

destruction system **10**. This list is meant to be illustrative and is not comprehensive or otherwise limiting. Table 2 combines the different chemical agent fills into groups of chemicals having similar chemical reactivities. In accordance with Table 2, recovered chemical munitions can be grouped into four basic groups for chemical neutralization treatments.

Table 2: Chemical Groupings

Chemical Group	Individual Chemical Fills
Organics	acrolein, bromoacetone (BA), bromobutanone (bromessigester), bromobenzyl cyanide (CA), chloroacetone, chloroacetophenone (CN), mustards (H, HD, HS, HT), chloroacetophenone/chloropicrin/chloroform (CNS), dichloroethylthiodiethylether (Vesicant T).
Chloride Family	phosgene (CG), chloropicrin (PS), $SnCl_4$/PS (NC), $SnCl_4$, $TiCl_4$ (FM), chloropicrin/phosgene (PG), cyanogen chloride (CK).
Organo-arsenics	lewisite (L), phosgene/diphenylchloroarsine (PD), diphenylchloroarsine (DA).
Oxidizer	chlorine (Cl_2)

Several treatment chemicals can be used to neutralize the chemical agent fills as grouped in Table 2, including monoethanolamine (MEA), aqueous hydroxide, aqueous bisulfite, water, denatured alcohol, acetone, hydrogen peroxide, aqueous hypochlorite, and combinations thereof, among others. The U.S. Army is using MEA or MEA/NaOH for organics and organoarsenic groups from Table 2. Arsenic is a special hazard because of its persistent toxicity even after treatment of the original chemical agent. The organics often yield multiple species upon basic hydrolysis or aminolysis. These species may be hazardous wastes, but they will not have the handling or transportation restrictions associated with the highly toxic chemical agent starting materials. The Chloride group is preferably treated with aqueous hydroxide, while chlorine is treated with aqueous bisulfite. The chlorine reaction is spontaneous and limited only by the solubility of

chlorine gas in the aqueous phase. In the absence of dissolved metals, the products of bisulfite treatment are non-hazardous.

All of the treatment reactions are exothermic. Some reactions, such as phosgene or chloroform with hydroxide, generate sufficient energy to be a concern in a batch process. However, the explosive destruction system's containment vessel **12** has a large thermal mass because of the thickness of the vessel's walls, so the heat of reaction will only aid in warming the vessel **12** and will not create dangerous overpressures.

In addition to the chemical agents, any residual explosives must be treated. The shaped charges used to access the munition include a linear shaped charge **19** to open the shell and at least one dedicated conical shaped charge **21** designed to pierce the burster at the same time as the shell is opened. This yields an extremely high probability of detonating the burster charge. Unfortunately, there is never a complete guarantee that the explosives will detonate because these munitions may have been buried for more than 50 years in uncontrolled conditions and may have undergone dramatic chemical and physical degradation. It is expected that the shaped-charge **21** will detonate, or at least ignite, the explosives. Traces of unreacted explosives (likely TNT or Tetryl) may remain after the initial detonation. Experiments have shown that solutions of TNT or Tetryl and individual chemical agents, when exposed to MEA, always treated the explosive as well as the chemical agent within one hour at 40 °C. Actual reaction inside the explosive destruction system **10** may be slower because solubility limits the reaction rate. Aqueous hydroxide efficiently destroys nitrated aromatics only if the particles are small and the

reaction is agitated. However, treatment of explosives in the EDS is meant only to clean up traces of explosives, not as a method of bulk explosive destruction.

The speed of neutralization treatment is limited by the solubility of the chemical warfare material in the treatment medium. If the agent has polymerized or degraded, the treatment may take longer. Inorganic chlorides may yield voluminous precipitates of oxides/hydroxides under these conditions, so agitation and excess treatment chemicals are required. In a preferred embodiment of the explosive destruction system **10**, the chemicals are heated to near the boiling point and agitated, accelerating the reactions.

Since any hardware inside the vessel **12** must withstand the explosive blast, the inventors have opted to both heat and agitate the vessel externally. As shown in FIG. 4, in a preferred embodiment the vessel **12** is heated with a plurality of 1-kW band heaters **31** using a feedback control system. Typically, it takes 3 to 4 hours to heat the contained fluids to 100°C. Fluid temperature can be controlled within ± 4°C. The treatment chemicals can also be heated to about 60°C in the tanks **27** before they are injected into the vessel **12**.

Referring again to FIG. 9, in the preferred embodiment the vessel **12** is also mounted on pillowblock bearings **33** allowing it to tilt forward and backward for agitating the contents of the vessel. A hydraulic system **35** is used to oscillate the vessel **12** between ± 40 degrees from the horizontal position. Typically, the entire stroke through 80 degrees takes about 9 seconds. The vessel **12** can also be stopped in any position to aid in draining or sample collection. FIGs. 11 and 12 show an alternative embodiment in which the vessel **12** is rotated about its longitudinal axis by a motor **43**. A motor-driven

agitation system **43** has advantages in that no hydraulic mechanism is required to be located under the trailer **29** floor, thus simplifying the system and eliminating the potential for chemical damage or contamination of the hydraulic system **35**.

A series of tests have been conducted to qualify and demonstrate the one-pound (TNT equivalent) explosive destruction system **10** as initially configured. Initial tests evaluated the chemistry, heating, chemical feed, and vessel agitation. The second set evaluated explosive containment.

In the first treatment test, the inventors treated methyl salicylate (oil of wintergreen) with MEA and NaOH. Oil of wintergreen has been used by the U.S. Army as a surrogate chemical fill and chemical agent simulant. It was useful in this test because it reacts with both the MEA and NaOH treatment chemicals to form two different products. All aspects of the explosive destruction system **10** worked as expected. The effluent was analyzed using both LCMS and NMR. The final concentration of oil of wintergreen was below the detection limit of 20 ppm.

In a second test, the inventors treated one pound of chlorine with sodium bisulfite. Chlorine is one of the fills that the explosive destruction system **10** is designed to destroy. The chlorine was generated inside the containment vessel **12** using a reaction of calcium hypochlorite and methane sulfonic acid. Again the system **10** worked as expected and the concentration of chlorine in the effluent was below the detection limit.

The initial explosive containment tests used bare charges of C4 explosive. FIG. 1 shows a charge and detonator assembled in the vessel. The first test used 170 grams of C4 (200

grams TNT equivalent), which matches the combined explosive load from the burster and the shaped charges for a 75mm artillery test.

This was followed by a 25 percent over-test with 474 grams of C4 (1.25 pounds of TNT equivalent) to qualify the vessel for repeated use with one-pound TNT equivalent. Both tests were successful. Helium leak measurements before and after the detonations showed no change in the leak rate, or in some cases a decrease in the leak rate was observed, indicating that after detonation the seal **20** for the containment vessel **12** actually improved.

The shaped charges **19** and **21** and fragment suppression system **11** were then demonstrated on a series of tests with each of the three munition types. The special evaluation test hardware munitions for some of these tests were filled with borate to provide a non-hazardous surrogate for the chemical agent fill. The borate was neutralized with vinegar. The fragment suppression system **11** worked as designed. Visual inspection revealed no damage to the vessel **12** other than superficial scratches.

As an additional test of the entire explosive destruction system **10**, a test was conducted with a phosgene filled bottle. The objective was to demonstrate the functionality of the chemical treatment system in concert with the explosive opening and firing system and the chemical sampling system on a combined chemical and explosive hazard. This test was the closest replica to the actual field use of the explosive destruction system and exercised all aspects of the system. A commercial lecture bottle containing one pound of phosgene gas was ruptured with linear shaped charges and the contents were treated with aqueous hydroxide. The system worked well during all these tests.

Finally, the explosive destruction system of the present invention has now been used to destroy actual field recovered chemical munitions. More specifically, seven 4-inch phosgene-filled Stokes mortars, seven 4.2-inch mustard-filled (blister agent) mortars, and five 4.5-inch mustard-filled projectiles have been successfully destroyed using the present invention. Furthermore, six M139 bomblets containing the nerve agent Sarin (GB) were destroyed using the present invention. In all of these destruction operations, the explosive destruction system of the present invention successfully: (1) contained the blast and overpressure during the detonation as verified by chemical agent air monitors; (2) cut open the mortars, projectiles, and bomblets using the linear shaped charge **19** as verified by post destruction inspection; (3) detonated the mortar, projectile, and bomblet explosive components (when present) as verified by post destruction inspection; (4) added reagent chemicals and chemically neutralized the chemical payload within the munition as verified by laboratory analysis; (5) agitated and heated the contents within the vessel **12** for the mustard and nerve agent mortars, projectiles, and bomblets to facilitate chemical treatment and neutralization; (6) drained the neutralized agent from the vessel **12** and used carbon filters to clean the vessel gases; and (7) continued to meet all helium leak-test requirements for the system **10**.

Demonstrating a one-pound TNT equivalent explosive destruction system has proved the capability and advantages of the present invention. Of course, the present invention is also capable of treating larger explosively configured munitions, simply by enlarging the explosive containment structures. A 3.5-pound TNT equivalent system is presently being fabricated.

It should be clear to those of skill in the art that numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that while the invention has been described in this specification with some particularity, it is not intended to limit the invention to the particular embodiments provided herein. On the contrary, it is intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined in the appended claims.